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**Hard Water as a Limiting Factor in the
Distribution of *Isoëtes echinospora***

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Isoëtes in Wisconsin has been shown by Swindale and Curtis (1957) to be a typical member of the soft water flora. Tryon et al. (1953) show it distributed in soft water areas, but absent from areas where hard water lakes are common. Moyle (1945) reports the Quillworts in Minnesota as members of a flora limited to a single chemical type: the soft water lakes found in the northeastern portion of the state.

Although soft water is the typical location of Quillworts, they have been found in hard water. Lee reports *Isoëtes echinospora* from Moshawquit lake. This Wisconsin lake has a specific conductance of 173 micromhos/cm and a total alkalinity of 98 mgm/l CaCO₃, which exceeds the upper limit of tolerance as reported by Moyle (1945). Seddon (1965) reports it in two hard water lakes in Wales, Llyn Llygerian and Llyn Llywenan.

Moyle (1945) suggests that the aquatic species of *Isoëtes* are found in soft water because they can not tolerate a total alkalinity

of above 50 mgm/l CaCO_3 , but since they have been reported from other than the usual soft water sites, the distribution can not be completely attributed to water chemistry. Seddon (1965) concluded from field observations that competition is responsible for the restriction of *I. echinospora* to soft water.

To determine if Quillworts could survive and grow in hard water without competition, *I. echinospora* var. *braunii* (Dur.) Engelm. was grown under laboratory conditions of varying water chemistry during one summer growth period.

TABLE I. WATER ANALYSIS OF EXPERIMENTAL TANKS¹

	<i>total alkalinity (CaCO₃ mgm/l)</i>	<i>pH</i>	<i>conductance (micromhos/cm)</i>	<i>water color (Pl-Co units)</i>
Crooked Lake	29	7.5	119	15
Crystal Lake	92	7.6	231	35
Wis. River	112	8.2	282	65
Fish Lake	148	7.9	304	35
Pretty Lake	160	8.3	483	40
Lake Ripley	184	8.6	431	20
Lake Wingra	228	7.8	643	38
Merrill Springs	281	8.0	585	30

¹ Water analysis furnished by Mr. Ronald Poff, Water Classification Specialist, Wisconsin Department of Natural Resources, Madison, Wisconsin.

Eight 10-gallon aquaria were filled with water and substrate, each from a specific body of water. Water sources were chosen to provide a range from very soft to very hard water (see *Table I*). Experimental plants were collected from Crooked Lake, Burnett County. For each tank, ten plants were randomly selected from the collection, weighed, the number of leaves counted and measured, and then planted. Twelve hours of light was supplied daily by Gro-lux fluorescent bulbs to provide 100 ft-c of illumination at the water surface. Weekly water analyses determined that little change in water chemistry occurred over the experimental period.

At the end of 21 weeks all plants were still surviving in the soft water control (Crooked Lake) and the hard water aquarium from Ripley. Seventy per cent of all the experimental plants survived; they grew an average of 5 new leaves and had 2 cm of leaf and root growth, the same as the average in the soft water control tank. Sporulation did not occur.

At the termination of the experiment the plants were replanted, additional hard tap water (280 mgm/l CaCO_3) was added to each tank to replace evaporation loss, and continuous illumination at a high intensity was provided. After five months all plants still survived and appeared healthy. Several were sporulating.

While the results of this experiment are tenuous due to the death of 30% of the experimental plants, they do support the belief that water hardness is not the single major limiting factor in distribution. The continued growth and sporulation with increased illumination, plus the fact that the two tanks which had 100% survival were significantly less colored than the others (see *Table I*), indicates that the amount of light reaching the plants may be an important factor in the distribution of *Isoëtes echinospora* var. *braunii*.

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